**Exemption No. 10174**

**UNITED STATES OF AMERICA**
**DEPARTMENT OF TRANSPORTATION**
**FEDERAL AVIATION ADMINISTRATION**
**RENTON, WASHINGTON 98057-3356**

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| In the matter of the petition of<br><br>**The Boeing Company**<br><br>for an exemption from § 25.981(a)(3) at Amendment 25-102 of Title 14, Code of Federal Regulations | **Regulatory Docket No. FAA-2009-1058** |

## GRANT OF EXEMPTION

By letter dated November 4, 2009, Mr. Ronald J. Hinderberger, Lead Administrator, The Boeing Company, P.O. Box 3707 MC 67-LR, Seattle, WA, 98124-2207, petitioned for an exemption from the fuel-tank safety provisions of § 25.981(a)(3), as amended by Amendment 25-102, of Title 14, Code of Federal Regulations (14 CFR) as it relates to the structural lightning protection of wing fasteners. If granted, the exemption would permit type certification of Boeing Model 747-8/8F airplanes.

**The petitioner requires relief from the following regulation:**

**Section 25.981(a)(3) as amended by Amendment 25-102:**

(a) No ignition source may be present at each point in the fuel tank or fuel tank system where catastrophic failure could occur due to ignition of fuel or vapors. This must be shown by:

(3) Demonstrating that an ignition source could not result from each single failure, from each single failure in combination with each latent failure condition not shown to be extremely remote, and from all combinations of failures not shown to be extremely improbable. The effects of manufacturing variability, aging, wear, corrosion, and likely damage must be considered.

**The petitioner supports its request with the following information:**

This section presents the relevant information from the petitioner's request. Complete petition information is available at the Department of Transportation's Federal Docket Management System, on the Internet, at http://www.regulations.gov, in docket no. FAA-2009-1058.

## Introduction

The FAA has issued Policy Memorandum ANM-112-08-002 to address the impracticality of compliance to 14 CFR25.981 (a)(3) amt 102 with regards to structural lightning protection. 14 CFR 25.981(a)(3) at amendment 25-102 requires:

*(a) No ignition source may be present at each point in the fuel tank or fuel tank system where catastrophic failure could occur due to ignition of fuel or vapors. This must be shown by:*

*(3) Demonstrating that an ignition source could not result from each single failure, from each single failure in combination with each latent failure condition not shown to be extremely remote, and from all combinations of failures not shown to be extremely improbable. The effects of manufacturing variability, aging, wear, corrosion, and likely damage must be considered.*

Boeing is petitioning for an exemption to 14 CFR 25.981(a)(3) for fuel tank structural lightning protection. The ANM-112-08-002 FAA policy memorandum provides the following alternate requirements:

1. Instead of compliance with the requirements of § 25.981 (a)(3), the applicant must show that the design includes at least two independent, effective, and reliable lightning protection features (or sets of features) such that fault tolerance to prevent lightning-related ignition sources is provided for each area of the structural design area proposed to be exempt from the requirements of that regulation. Fault tolerance is not required for any specific design feature if:
    a. providing fault tolerance is shown to be impractical for that feature, and
    b. fuel tank vapor ignition because of that feature and all other non-fault-tolerant features, when their fuel tank vapor ignition event probabilities are summed, is shown to be extremely improbable.
2. The applicant must perform an analysis to show that the design, manufacturing processes, and airworthiness limitations section of the instructions for continued airworthiness include all practical measures to prevent, and detect and correct, failures of structural lightning protection features because of manufacturing variability, aging, wear, corrosion, and likely damage.

## Discussion

Boeing has concluded that compliance to 14 CFR 25.981(a)(3) for fuel tank structural-fastener lightning protection would require three independent layers of protection. For fuel tank fasteners, there are no practical means in current technology to obtain triple redundant means of protection in all locations. Another option would be to apply [an] inspection interval which monitors the health of each fastener that penetrates the fuel tanks. With thousands of fasteners on the wing of the 747-8/8F, this option is impractical. Increasing the number of in-tank inspection intervals could also have a potential unintended consequence of damaging the lightning protective features or other components inside the fuel tanks.

**Proposed Risk Mitigation**

As discussed in the FAA Policy Memo, Boeing will submit detailed Proprietary information to the FAA about the measures taken in the 747-8 design to provide practical structural lightning protection. In general, the 747-8/8F, lightning protection features are based on state-of-the-art industry design practices for aluminum wing structure including inherently conductive low resistance current paths that have been used in existing in-service designs. Further, Boeing proposes to enhance the lightning protection by incorporating additional fault tolerant protection for fasteners in areas of potential swept lightning attachment (referred to as Zone 2) by cap sealing the fasteners to contain a possible spark in the event that the primary protective features fail, thereby increasing the level of fuel-tank safety. Boeing will demonstrate that the structure in Zone 3 (and Zone 2) is capable of providing fault-tolerant protection to conducted currents, which is the only Zone 3 requirement.

For pre-Amendment 25-125 airplanes, Boeing will comply with FAR 26.35 and FAR 26.33. A flammability exposure analysis will be provided similar to the analysis provided for the 747-400 showing that the main wing tanks of the 747-8 are either equivalent to the conventional unheated aluminum wing tank (reserve and surge tanks) or are below 7% fleetwide flammability exposure (inboard and outboard main tanks) per 26.33(c). The center tank of the 747-8 utilizes an inerting system to meet the flammability exposure criteria of Part 25 Appendix M. Performance will be demonstrated and documentation of compliance will be submitted for approval per CP 4288.

Boeing will show that the structural fastener design for the majority of the model 747-8/8F wing will have two reliable and effective features for lightning protection. Testing will show that the fastener installation will be safe for applicable lightning zone requirements and will not produce any sparks inside the fuel tanks. Additionally, Boeing will show by test that a cap seal, as a second layer of protection, will contain a spark should one occur from a failed fastener. For the limited areas in which a single failure of a fastener could result in loss of both protection features, or any other area where a single layer of protection is all that can practically be provided, a safety assessment will be done to show that the probability of a lightning related fuel tank ignition event is extremely improbable. The systems supporting structure will also be analyzed as part of the fault tree assessment to ensure that they meet the requirements in the policy memo. Additionally, Boeing will utilize production procedures in order to minimize the risk of mis-installed protective measures, and to identify and repair errors in such a way that the lightning protection features will be maintained. The instructions for continued airworthiness and repair procedures will also be provided to ensure the protection features are maintained throughout the life of the airplane.

Boeing has utilized all practical measures to meet the requirements of 14CFR 25.981(a)(3) for fuel tank structural lightning protection. Boeing has designed the 747-8 fuel tank structure to be fault tolerant for all but two failure modes as discussed later in this section. A detailed FMEA will be provided as part of the compliance documentation. A test program to demonstrate fault tolerance has been developed as a part of the compliance demonstration. The test plan has been submitted, and the test results will be documented for compliance.

As described in reference (c), the 747-8 design utilizes properly installed structural fasteners and cap sealing to provide fault tolerant structural lightning protection. Boeing considered additional design features to the fuel tank structure to achieve dual fault tolerance for compliance to 14CFR 25.981(a)(3), but these were found either impractical to implement or insufficient to provide any additional lightning protection.

Examples of design considerations were:

- Conductive steel fasteners – Widespread use results in higher weight, fuel burn and associated emissions, and higher risk of corrosion. Design with all steel fasteners is still not dual fault tolerant.

- Additional sealant – Reduces structural inspectability for cracks and corrosion, potentially reducing overall fleet safety. Would result in additional weight, fuel burn and emissions.

- Composite skin protection methods – Not applicable to aluminum design. Note the majority of these methods are intended to increase conductivity of the outer tank surface in the area local to the fastener heads, which aluminum structure provides inherently.

- Fuel tank bladders or double walled fuel tanks – Would result in a new enclosed fuel vapor space, which would pose an additional vapor ignition threat during a lightning attachment and thus does not increase safety. This would also increase weight which increases fuel burn and emissions, plus reduces usable fuel tank volume which reduces range. The bladders also inhibit structural inspectability inside the tank.

- Spot Bonds – Spot bond is a local bond in which the primer is removed at the internal fastener interface with structure. Removing primer increases corrosion risk, detracting from any benefit of increased conductivity offered by the spot bond. The spot bonds would still be subject to faults and does not result in a dual fault tolerant design.

- Fastener Free Wing Structure – Structure that does not have any fasteners would not be susceptible to lightning protection faults associated with fasteners but is not necessarily dual fault tolerant. It is not possible to produce raw materials large enough to create monolithic wing panels or spars in dimensions that the 747-8 requires and monolithic designs would reduce structural crack tolerance. Using adhesives instead of fasteners to bond major components represents a radical departure from established metallic wing primary structure experience.

These types of designs were determined to be impractical due [to] lack of safety benefit, increased weight, increased fuel burn, increased emissions, and reduced inspectability during maintenance.

Boeing will provide a System Safety Assessment (SSA) as part of compliance for the 747-8/8F programs. A fault tree analysis will be included in the SSA which will quantify the single failures, and demonstrate that the probability of a fuel-vapor ignition in the life of the 747-8 fleet is extremely improbable.

The only faults identified, for which the design is not fault tolerant, are the potential for a latent crack in structure or a bolt failure which also causes the fastener nut (or collar) to release with sufficient force to tear free the associated cap seal. Note that both of these failure modes are identified in the FAA Policy Memo, as typical situations where applicants have been unable to identify practical means for fault tolerance. In each of these cases, sparking due to these failures would only occur if there was a direct attachment to the local area of the failure. Boeing will demonstrate sparking does not occur due to these failures during conducted current tests. For both of these failure modes, Boeing has been unable to identify a practical alternative to provide a protection to the failure mode for direct attachment. A numerical assessment will be provided demonstrating the probability of a fuel vapor ignition due to these failures is extremely improbable (and thus unlikely to occur in the life of the fleet). Service experience on the 747-400 shows each of these failures to be rare. The failure rate for fasteners will be established using in-service data for fasteners on Boeing airplanes. The expected rate of occurrence of structural cracking will be conservatively based on Boeing's structural fatigue methodology. This methodology is based on test and service experience, and ensures that the presence of fatigue cracks is minimized during the life of the airplane.

Boeing has implemented in the design all practical measures for structural [lightning] protection. Boeing is currently reviewing the manufacturing processes to ensure the lightning protection features are implemented as intended on the drawings and are maintained. The repair procedures will be reviewed to ensure the lightning protection features will be maintained throughout the life of the airplane. Instructions for Continued Airworthiness will be developed and included in the certification documentation. A complete analysis of the manufacturing process and repair procedure will be part of the System Safety Assessment and submitted for compliance per CP 3308 deliverable number 62.

**Issue of Public Interest**

Boeing is working to improve the efficiency of the 747 model by a redesign. The 747-8/8F has additional capability and capacity over the 747-400 model. For lightning protection, the 747-8/8F has additional features to enhance safety and protect the fuel tanks from sparking due to a lightning event. All practical measures have been utilized. Additional features to directly meet the rule are impractical (as the FAA Policy Memo notes) and would potentially add significant cost, weight, and maintenance to the airplane without a measurable safety benefit. Further, additional lightning protection features could inhibit the ability to inspect the structure (reducing safety).

Requiring the 747-8/8F to attempt to directly comply with this rule would significantly inhibit Boeing's ability to design and certify the airplane on a competitive schedule. It would also render the 747-8/8F to be of lesser value to the public interest with no commensurate increase in safety. Many Boeing customers are depending on the 747-8/8F to meet their business needs. New 747-8/8F aircraft will typically replace older, less-fuel-efficient models, reducing the public expense for fuel consumed in air travel and freight delivery. Therefore, Boeing believes that it is in the public interest for the FAA to grant this exemption.

**Effect of Exemption on Safety**

With current design practices for lightning protection, Boeing aircraft designs have accumulated in excess of 600 million revenue-service flight hours with no lightning-related events. Prior to these designs and service hours, there were two commercial-jet-transport hull-loss events which are believed to have been caused by lightning strikes (reference ARAC Report: 1998 ARAC Fuel tank Harmonization Working Group report, Task Group 1 Service History / Fuel Tank Safety Level Assessment). The first was in 1963, which led to the development of lightning-protection standards for fuel tanks. The second and last event was in 1976 and also resulted in improvements in fuel tank lightning protection. In addition, both events utilized JP-4, which is a wide cut, higher volatility fuel rarely used today. The 747-8/8F airplanes will not be certified for use with JP-4 or other wide-cut fuels. The hours accumulated since the last event represent over 6 times the hours accumulated with earlier designs through 1976. The accident-free fleet history since 1976 shows current Boeing wing designs have sufficient protection against lightning-induced fuel-tank ignition events.

This safety record, for the fuel system designs upon which the enhanced Boeing 747-8/8F design is based, indicates that the proposed fuel-tank lightning protection design of the model 747-8/8F will be safe.

**Conclusion**

Boeing is petitioning for an exemption from 14 CFR 25.981(a)(3) at amendment 102 for fuel-tank structural lightning protection. The Boeing model 747-8/8F is nearing the end of its design and initial build cycle. Granting this exemption will allow Boeing to complete its design and certify the 747-8/8F for delivery. The proposed design for the 747-8/8F will provide an appropriate level of safety against lightning-induced fuel-tank ignition, and will be shown to comply with the alternative requirements provided in the FAA policy memo ANM-112-08-002.

**Federal Register publication**

A summary of this petition was published in the *Federal Register* on January 20, 2010. The FAA received no comments.

**The FAA's analysis**

In May 2001, the FAA issued the "Transport Airplane Fuel Tank System Design Review, Flammability Reduction, and Maintenance & Inspection Requirements" final rule (Docket FAA-1999-6411, effective June 6, 2001) that was adopted as Amendment 25-102. This amendment added specific ignition-prevention requirements and a new flammability-minimization requirement to § 25.981.

The amended ignition-prevention requirements in § 25.981(a)(3) require consideration of factors such as aging, wear, and maintenance errors, as well as the existence of single failures, combinations of failures, and latent failures that may be the cause of ignition sources in fuel tanks.

Section 25.981, as amended by Amendment 25-102, requires that airplane designs be protected, from the effects of structural lightning, with features that are failure tolerant. Prior to this

amendment, only § 25.954 had been applied to lightning protection of fuel tanks. That provision requires only that the airplane design prevents ignition of vapors in the tank with no consideration for anticipated design failures, aging, and wear, or maintenance errors.

Systems with potentially catastrophic failure modes would typically meet the requirements of § 25.981(a)(3) by providing at least triple redundancy in their protective features with periodic inspections, or dual-redundant features with continuous system monitoring to reduce the latency period. Dual-redundant design schemes could only comply with § 25.981(a)(3) when combined with either regular inspections at very short intervals or a monitoring device to verify the functionality of the protective features. Inspection of the various design features may be difficult or impossible if the feature is internal to the fuel tank and part of the wing structure.

When § 25.981 was applied to the structural lightning aspects of new airplane designs, applicants found it was impractical to meet the standard and incorporate additional protective features. The FAA issued two exemptions and developed new policy. The two exemptions were for the Dassault Falcon 7X, issued on April 20, 2007, and the other was for the Hawker 4000, issued on August 28, 2008. On May 26, 2009, following a public-comment period, we adopted new policy that defined criteria that we would consider regarding granting of exemptions and issuance of special conditions for structural lightning protection. Boeing provided substantiation in their exemption request that meets the criteria of this policy.

As it applies to fuel-tank lightning protection for basic airframe structure (airplane skins, joints, ribs, spars, stringers, and associated fasteners, brackets, and coatings), the petitioner argues that both the addition of a third, independent, ignition-source protective feature, and providing sufficient monitoring to detect latent failures in a dual-protective feature, are impractical for certain areas of metallic airplane-wing structure. As discussed in the policy memo, the petitioner evaluated possible means of providing additional protective features as a condition of this exemption and found it was impractical to incorporate those features into the Boeing 747-8/8F. Boeing also identified two features through lightning tests and analysis that are not fault tolerant. These are the potential for a latent crack in structure, or a bolt failure which also causes the fastener nut (or collar) to release with sufficient force to tear free the associated cap seal. Boeing showed that the probability of fuel-vapor ignition, due to these non-fault-tolerant features, was extremely improbable, which satisfies the criteria in the policy memo.

We agree with the petitioner that compliance with paragraph (a)(3) would require a combination of redundant protective features, and a high level of reliability of those features, that is excessively expensive to produce and maintain using available technology. Lightning energy can be transferred to fuel tanks installed in wings through the many fasteners and other structural elements. It is impractical to provide either continuous monitoring of the “health” of the protective features for these structures, or to inspect them frequently enough to detect latent failures. These features are typically integral to the fuel-tank structure, or internal to the fuel tanks, requiring access into the tank to verify the integrity of the feature. Inspections of airplane structure requiring fuel-tank entry may be scheduled only once or twice during the life of the airplane.

As discussed in the preamble to Amendment 25-102, conventional, unheated, aluminum wing tanks minimize fuel-tank flammability exposure, as required by § 25.981(c). Even if a latent failure of a protective feature occurred for such a tank, the risk of lightning-induced fuel-tank explosions is relatively low when the tank is fueled with low-volatility fuels such as Jet A, as

demonstrated by the service experience of these tanks. Because of the impracticality of full compliance with § 25.981(a)(3) for lightning protection and the reduced flammability exposure of these tanks, we believe granting an exemption is in the public interest if applicants can show that their design provides practical dual-protective features for fuel-tank structural lightning protection that are both independent and robust, and show the probability of fuel-tank ignition to be extremely improbable for any non-fault-tolerant features.

The Boeing petition states that Boeing will comply with §§ 26.33 and 26.35, proposing acceptable flammability-exposure analysis and inerting systems. The wing fuel tanks on the 747-8/8F are constructed of aluminum and by inspection would meet this fuel-tank flammability requirement. Boeing has also prohibited use of JP-4 and other wide-cut fuels to limit flammability exposure. The center wing fuel tank on the 747-8/8F has a nitrogen inerting system that also must meet this flammability requirement. Therefore, the 747-8/8F will satisfy the flammability criteria defined in § 25.981(b) and the policy memo.

For the wing-skin fasteners of the tanks in Zone 2 (as illustrated in AC 20-53B), Boeing must demonstrate that at least two independent and effective means of lightning protection are provided and reliably maintained. Boeing proposes lightning-protection features for the 747-8/8F based on state-of-the-art, industry-design practices for aluminum wing structures including inherently conductive, low-resistance current paths that have been used in existing in-service designs. Boeing is enhancing lightning-protection features by incorporating additional fault-tolerant protection for fasteners in areas of potential swept-lightning attachment (referred to as Zone 2) by cap-sealing the fasteners to contain a possible spark in the event that the primary protective features fail, thereby increasing the level of fuel-tank safety. Boeing will also demonstrate that the structure in Zone 3 (and Zone 2) is capable of providing fault-tolerant protection to conducted currents, which is the only Zone 3 requirement.

To substantiate the effectiveness of lightning-protection features, Boeing must provide analysis and test data. Boeing has agreed to this as part of their petition request.

In addition to validating independent and effective design means of lightning protection for certification on new production airplanes, § 25.981(b) requires establishing critical design configuration control limitations (CDCCLs), inspections, and other procedures to prevent the development of ignition sources within the fuel-tank system as the airplanes progress through their service life. These limitations, inspections, and procedures must be included in the Airworthiness Limitations Section of the Instructions for Continued Airworthiness required by § 25.1529. Boeing states that they will provide maintenance information, which will be included in the Instructions for Continued Airworthiness.

Boeing has identified maintenance-inspection tasks with appropriate inspection intervals to ensure the needed reliability of proper wing-fastener installation and sealant coverage. These actions should maintain the lightning-protection characteristics of these two independent protective features. Boeing has identified maintenance-manual procedures that restore the protective features to the same level and with the same products and techniques as the original design specifications.

The FAA considers the petitioner's request to be in the public interest because the Boeing Model 747-8/8F airplane design provides an acceptable level of safety, and full compliance to § 25.981(a)(3)is impractical. Full compliance would require significant modifications to the fuel-

tank design; introduce additional complexity into the manufacturing and quality process, as well as into maintenance procedures that have not been shown to be completely effective; and add significant cost and schedule impact to the Boeing Model 747-8/8F airplane program. The 747-8/8F meets later safety standards, providing improved safety over that of airplanes it is replacing in the fleet. In addition, new 747-8/8F aircraft typically will replace older, less-fuel-efficient models, reducing the public expense for fuel consumed in air travel and freight delivery. In addition, the Boeing Model 747-8/8F airplane type-certification program is near completion. Without this exemption, Boeing would not receive design approval for the aircraft in a timely manner, delaying upgrading of the fleet safety-and-efficiency improvements. Delay would also cause disruption to several major corporations in the US and the world that are anticipating the imminent delivery of the Boeing Model 747-8/8F airplane to meet their business needs.

The FAA has considered the information provided by the petitioner and has determined that it has sufficient merit to warrant a grant of exemption. Note that the outcome of the conditions associated with the granting of this exemption may affect the regulatory compliance of the 747-8/8F if analysis, test data, and maintenance information is not provided as stated by the petitioner.

**The FAA's decision**

In consideration of the foregoing, I find that a grant of exemption is in the public interest. Therefore, pursuant to the authority contained in 49 U.S.C. §§ 40113 and 44701, delegated to me by the Administrator, The Boeing Company is hereby granted an exemption from the requirements of 14 CFR § 25.981(a)(3) as it relates to 747-8/8F fuel-tank structural lightning protection with the following provisions:

1. Instead of compliance with the requirements of § 25.981(a)(3), Boeing must show that the design includes at least two independent, effective, and reliable lightning-protection features (or sets of features) such that fault tolerance to prevent lightning-related ignition sources is provided for the structural-fastener design and systems-supporting structure of the wing. Fault tolerance is not required for a latent crack in structure, or a bolt failure that also causes the fastener nut (or collar) to release with sufficient force to tear free the associated cap seal, if:

    a. Boeing shows that providing fault tolerance is impractical, and

    b. Boeing shows that fuel-tank vapor ignition, because of each of these features and all other non-fault-tolerant features, when their fuel-tank vapor-ignition event probabilities are summed, is extremely improbable.

2. Boeing must perform an analysis to show that the design, manufacturing processes, and airworthiness-limitations section of the instructions for continued airworthiness include all practical measures to prevent, and detect and correct, failures of structural lightning-protection features because of manufacturing variability, aging, wear, corrosion, and likely damage.

Issued in Renton, Washington, on December 14, 2010.

*/s/ Ali Bahrami*

Ali Bahrami
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Aircraft Certification Service